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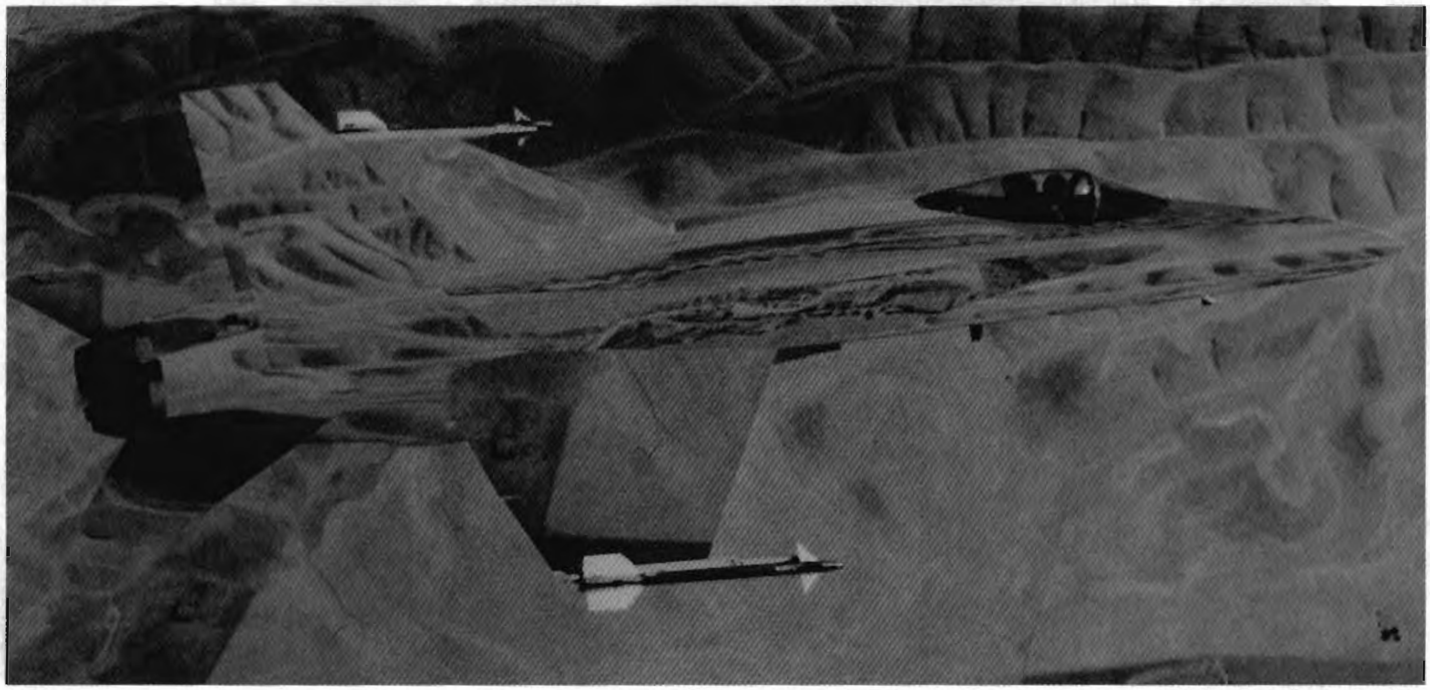

PHOTO ILLUSTRATION BY JOHN BRETSCHNEIDER, AFJ STAFF

Taking on a GHOSTLY appearance

Can computer-assisted 'camouflage' make military systems 'disappear'?

Military hardware in plain view can be made to appear transparent, the author says, by projecting a background scene on the viewer's side of the object. The illustration above, put together by AFJ, shows how an F/A-18 can be camouflaged.

As we saw most recently in Iraq, modern battlefields are dominated by thoughtful integration of complimentary strategies, equipment and technology. These are, in fact, the components of victory for a military force. Recent conflicts involving U.S. forces have demonstrated repeatedly the value of these so-called "force multipliers." During many combat engagements, moreover, technologies designed to provide an enhanced ability to detect, target and deliver weapons with extreme accuracy have won wide acclaim. Too often, though, we overlook the complementary technologies that are being used to assure the survivability of military fighting platforms by making them harder to detect and, subsequently, more difficult to destroy. But those passive defensive measures, such as the "stealthy" design elements in modern fighter aircraft, also make major contributions to victory.

Most technological advances seen thus far in the area of defensive measures involve concealing military assets from detection by enemy forces by reducing, concealing or masking radar, acoustic and thermal signatures. Few if any advances, however, have been achieved in reducing or eliminating the visual profiles presented by military hardware within the visible light portion of the spectrum (400 nanometers to 700 nanometers; one nanometer is one-billionth of a meter.) Being able to do so would make military hardware less visible to the human eye.

Making a large, mobile military system — an object with a definable, opaque mass — "disappear" might be beyond technology's reach. However, it is possible to create the illusion that an object is transparent, no matter its size, shape or surroundings.

MORE THAN PAINT

The best way to meet this goal is believed to reside in the premise that transparency (as perceived by humans) is achieved when one can look "through" an object without detecting the object's shape, edges or texture.

It has long been the practice of developers of traditional forms of camouflage to simply paint equipment or military clothing with colors that generally resemble the expected battle space. Although moderately effective, these conventional methods are incapable of providing concealment within a dynamically changing combat environment.

An approach known as the Interactive Opacity Neutralization Array (IONA) concept was conceived to address the issues of concealing military hardware and weapons in plain view and to explore the viability of using modern technologies, such as projected or embedded digital video arrays, to overcome the limitations of past camouflage methods. The concept was also formed to examine the viability of creating an interactive system of concealment — one that could increase the effectiveness of battlefield combat systems by providing more protection for mission-critical assets during both day and night operations.

To develop a system that could conceal ships, airplanes, tanks, helicopters and even infantry units, a functional IONA would need to concentrate not on physical transparency, but rather on creating "perceived transparency." The envisioned solution postulates that technological means exist to make objects imperceptible to the human eye.

The design criteria envisioned for an IONA system would incorporate a variety of computer graphics technologies. All exposed surfaces of a combat vehicle would reflect imagery gathered from cameras mounted from six opposing perspectives. These would provide IONA-equipped vehicles with the ability to camouflage themselves against enemy forces. Since an IONA system would provide simultaneous interactive video displays (taken from multiple directions) that are, in turn, presented to the opposing surface, concealment and camouflage would be provided against all angles of attack.

DIGITAL VIDEO DISPLAYS

The basic tenet of the IONA concept rests in the presumption that the visual signature of any combat vehicle, whether stationary or mobile, can be reduced or eliminated by reducing its level of detectable opacity. That would occur through use of synchronized digital video displays on its surface that mirror the terrain and objects that are located on the opposing axis of the vehicle, as viewed by an enemy. Essentially, it is not the hypothesis that suggests reducing the visual signature of any vehicle can render it harder to see that drives such research. Rather, it is exploring how best to achieve this objective. It needs extensive study in order to design a fully operational opacity neutralization system.

In examining and testing various technologies that may contribute to creating a functional IONA prototype, preliminary analysis indicates a variety of commercially available technologies and resources hold considerable promise for direct application. Significant modifications likely will be required to adapt these technologies to create a fully functional IONA system that can withstand the rigors of modern wars. But preliminary research and discussions with selected engineers from various fields suggest that the existing state of the underlying technologies hold considerable promise for such an endeavor.

As currently conceived, the IONA could be constructed using several different, but complementary technologies. These include:

■ Incorporating a specially designed, tapered fiber-optic array, which is affixed along the surface areas of any vehicle to display captured video images received from a multiaxis display computer control panel.

BUILDING A GHOST PLATFORM

Before military systems can be made to seemingly disappear, researchers must determine the interrelations among the many variables that come into play when an image is seen. The author provided this preliminary analysis with hypothetical interrelations.

	Image quality		Image accuracy		Surface coverage		Neutral opacity
The primary invisibility equation:	Image quality	+	Image accuracy	+	Surface coverage	=	Neutral opacity
Subordinate variables:	Brightness Chrominance Shadow Contrast Saturation Hue Luminance Pixel density		Closing speed Focal length Image sync Frame rate Distance to the enemy Display angle Viewing angle		Surface geometry Absorption Image distribution Projection distance Projection angle		

SOURCE: Harold G. Campbell

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■ Using a lateral image-projection methodology that incorporates either white-light-laser technology or direct high-intensity video projection to create an interactive display surface.

■ Using a nonreflective, flexible and nonflexible light-emitting diode (LED) panel technology that could either be used independently or combined with other materials to create a heat-resistant laminate composite array capable of displaying video imagery throughout a vehicle's surface area. The LED configuration appears to hold the greatest degree of promise for unilateral system application.

In all these configurations, digital cameras mounted on gyrostabilizers would need to be strategically positioned on or within the vehicle to capture real-time video images of battlespace conditions. Depending upon the general direction or threat axis, estimated distance to the enemy, and the computed visual perspective axis, onboard computers would then adjust the display of the video images on the surface of the vehicle facing the opposing force in order to match the surrounding terrain. That would remove the edges, surfaces, contours, colors and textures of the vehicle.

Camera control and surface displays could be coordinated through input and use of radar data, Global Positioning System (GPS) coordinates or approximate

HOW 'INVISIBILITY' WORKS

The basic premise of "neutral opacity" is to create a camouflage system that allows a background scene to be viewed from the opposite side of a solid object.

SOURCE: AFJ research

JOHN BRETSCHNEIDER, AFJ STAFF

CHAMELEON CAMOUFLAGE

A number of visual factors must be balanced in order to achieve the appearance of invisibility using a projection system, including:

Original image
The above slice of a Bradley fighting vehicle photo is used as a neutral reference.

Hue
This is the wavelength of light that is seen as the spectrum of colors. The image slice above is shifted toward yellow and red.

Contrast
This shows the difference between the extremes (light and dark) and the midtones of an image. The contrast is too high at top and too low at bottom.

Brightness
The amount of light emitted or reflected by an object determines its apparent brightness. In the slice above, the brightness is set too high.

Saturation
Most objects have a dominant color with subtle undertones. Here, the dominant green is too vivid at the top and too muted at the bottom.

SOURCE: AFJ research

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enemy locations observed directly.

Each of these technologies would need to be fully examined, tested and refined (where appropriate) in order to deduce their individual and collective relevance and potential contribution toward creating a fully functional prototype IONA system. The display, resolution and array configuration, as presented through the various technologies available, appear capable of maintaining effective concealment.

Under combat conditions, the optimal level of display precision for concealment (despite the projection method employed) would naturally occur when the IONA array is provided with the known location, direction, and elevation of an opposing force, either through GPS, radar or observation data. But even when only the general direction of an enemy force is known, such a system could significantly outperform traditional methods of camouflage.

Under such a scenario, dynamically changing video images could be continually relayed to the leading edge and surface display areas of the IONA as the vehicle approaches an enemy's general location. These surface areas would subsequently reflect the topography, color, lighting and textures of the terrain that are located on the opposing axis of the vehicle, as provided by correlated camera movement. This interactive display technique would, theoretically, create a nearly transparent edge and surface profile for all exposed surfaces of the vehicle, providing enhanced concealment and, eventually, a significant degree of surprise among opposing military forces.

Along with limiting visual signature, interactive opacity neutralization also would heavily reduce an enemy's ability to accurately direct hostile fire against friendly forces — even after detection — by diffusing edge surfaces, color, lighting, surface contours and textures. Concealing and disguising these types of variables, in turn, would make it more difficult for enemy forces to discern the specific secondary variables necessary for effective fire control, such as speed, direction of movement and angle of attack.

By reducing the enemy's ability to detect friendly forces until they are within range to engage in offensive action, and by further reducing that enemy's ability to calculate the necessary fire-control solutions to effectively return fire once the battle has begun, the system would bring substantial tangible and psychological benefits to operational forces.

Considering the number of remarkable technological advances that have occurred during the past decade in the area of computing power and display systems, it's reasonable to conclude that this IONA concept is well within reach and that it's only a matter of time until we see this concept put to the test on some future battlefield. This raises a final question: Who will be first to build it? ■

Harold G. Campbell is a senior member of the faculty of California State University-Humboldt, College of Natural Resources and Sciences, Department of Computing Sciences. He has served on the CalState faculty for 14 years. He specializes in systems analysis and design, multimedia systems and spatial analysis systems.